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REPORT OF THE ENTOMOLOGIST.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., September 7, 1920.

SIR: I submit herewith a report of the work of the Bureau of Entomology for the fiscal year ended June 30, 1920.

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. E. T. MEREDITH,
Secretary of Agriculture.

CEREAL AND FORAGE CROP INSECT INVESTIGATIONS.

The work of this section, continued under the direction of W. R. Walton, has been very important.

EUROPEAN CORN BORER.—During the year the aspect of the corn-borer problem has altered greatly. When the last annual report was prepared the area of infestation in eastern Massachusetts was known to be about 1,000 square miles, but as the season progressed the larger force of scouts and more thorough work, made possible by the appropriation of $250,000, which became available July 24, 1919, resulted in the discovery of the insect throughout the Cape Cod peninsula. It was discovered also in outlying districts in Massachusetts and New Hampshire, where it was not previously known to occur. The infested area on the Atlantic coast at the end of the growing season of 1919 was about 2,000 square miles, and this has been still further increased during the last few weeks by the added area of several towns in Massachusetts contiguous to the old area. In the meantime the infestation in eastern New York has been found to include at least 1,000 square miles of territory in the counties of Fulton, Saratoga, Montgomery, Schenectady, Schoharie, and Rensselaer. During the month of September, 1919, a new area was discovered at the extreme western end of New York State, bordering on Lake Erie. Before the close of the season this infestation was found to include at least 500 square miles of territory. At about the same time a small infestation was located in Erie County, Pa. Both of the newly located infestations were in localities where broom factories existed, and which were known to have used imported broom corn. All the evidence so far accumulated indicates that these latter infestations were of several years' standing. The arrival in New York Harbor during the last few months of two shipments of broom corn from Italy which were found to be infested with both larvæ and pupæ of the pest indicates almost conclusively the manner in which the insect was originally introduced from Europe. Investigations made by the writer in Italy during June, 1920, indicated

that the earlier idea, that the insect had been imported in hemp, was surely erroneous. The rotting of the hemp before baling, according to the methods used in Italy, would without doubt destroy all insect life.

The extension of the infestation as described above vastly complicated the problem and, of course, necessitated a greatly increased expenditure for scouting and quarantine purposes. In view of this more serious aspect of affairs the Secretary submitted on December 12, 1919, a supplemental estimate calling for an appropriation of $500,000, the entire amount of which was to be immediately available, but Congress did not respond and the original appropriation of $250,000 became exhausted by the spring of 1920. This suspended the control work until June 7, 1920, when a new appropriation became available. By this time the adult insects had begun to issue, thus causing the abandonment of an extensive control experiment which was being conducted over an area of some 60 square miles in eastern Massachusetts. The delay in granting the appropriation also prevented extensive efforts at control in western New York, which had been planned by Federal and State forces. An appropriation of $400,000 became available June 7 of the present year, and a large force of workers was at once thrown into the field, principally for the purpose of scouting for possible new infestations and for the enforcement of the quarantine regulations.

As a result of the research work conducted during the year it has become apparent that the European corn borer has but one generation annually in New York, in contrast with the two generations occurring in New England. This fact indicates that the pest in all probability will prove less injurious in New York than in Massachusetts. In fact, the injuries inflicted by the insect in its New York environment as yet are comparatively slight. The chief danger to be feared from this situation is the possibility of spread to the great corn-growing States immediately to the westward of the present westward limit of infestation, and also to the southern half of the corn belt, and every effort is being made to prevent the artificial transportation of the pest to these areas. Flight experiments conducted for the purpose of determining the possible rate of natural spread of the insect have shown a maximum flight of 3,900 feet. This distance may, of course, be increased by subsequent observations on the second generation of adults. It has been shown that the adults are capable of emerging through 10 inches of loose soil and through 4 inches of tightly packed soil, thus indicating the uselessness of plowing under infested material as a means of destroying the larvæ.

A rather surprising development regarding the habits of the insect was the discovery this spring of the egg clusters in large numbers on several garden crops other than corn, such as beets, rhubarb, and less numerously on celery, lettuce, romaine, rye, plantain, sorrel, wild mustard, witch grass, morning glory, and snapdragon, all of which are new host records for the eggs. The larvæ have been found quite numerously in the leaf stems of beets as well as in the vines and pods of garden beans. These discoveries have necessitated a more stringent application of the quarantine regulations as regards garden crops other than corn. In the experimental work conducted in eastern Massachusetts the larvæ of the pest have been found to

feed upon cotton to some extent. Whether or not the bolls would be attacked has not yet been ascertained, because the cool climate prevailing there prevents the production of bolls on the plants grown for experimental purposes. The fact that the insect has been shown to feed upon cotton seems to indicate increased damage in case it should eventually become distributed throughout the cotton-belt States. This probability is given added weight by the discovery that under optimum temperature conditions the insect may undergo its complete life cycle in 30 days, and thus produce several generations each year. In fact, Del Guercio of Florence, Italy, told the writer in June that there are three generations a year there.

Generally speaking, at the close of July of this year the infestation in New England appears to be not quite so heavy as during 1919, although some few fields are still heavily infested.

That the insect may be easily transported into new territory by flood waters seems to have been amply proved by the fact that pupæ which were submerged in water for three days produced adult moths.

At the time of writing a total of 197 men are employed in the control work.

During the year several efficient pieces of machinery have been evolved for the purpose of destroying in the field infested materials such as cornstalks and stubble as well as weeds. One of these is a crushing apparatus through which the infested material is run and which applies a pressure of 90 tons to the square inch and is capable of handling 12 to 15 tons a day. Two of these machines are at present in operation. Another efficient piece of machinery is an oil-spraying burning machine of high power, capable of burning a strip 12 feet wide at one application, and with which it is possible to treat 12 to 15 acres in one day per machine.

Introduction of foreign parasites of the corn borer.—During the early summer of 1919 a preliminary investigation was made of European conditions, and a trained observer was established at Auch, in the south of France, to study the native parasites and to send them to this country in the effort to establish them in the infested parts of Massachusetts. Three species of parasites were found, and one shipment arrived in the autumn and the parasites were liberated in eastern Massachusetts. In May, 1920, the writer went to Europe and visited the regions in which the corn borer occurs in Belgium, France, and Italy, and arranged for the study of the native parasites at several points. He found that in Italy especially, where corn is extensively grown, the corn borer was always present in the fields, but in small numbers, and that nowhere was it necessary to take measures for its suppression. This indicated the existence of natural control, and it was found that four species of native parasites are known to the Italian entomologists. Arrangements were made for the shipment of parasite material to the bureau's agent at Auch, for comparison with the forms occurring at that point, and if it is found desirable other small parasite laboratories will be started in the south of Europe.

Grasshoppers.—Great numbers of grasshoppers, belonging principally to the species *Melanoplus atlanis* and *Camnula pellucida*, have continued to assail the crops in North Dakota. The northern and western counties have been most heavily affected, although consid-

erable damage has occurred in the Red River Valley. During July, 1920, the situation became desperate because the counties along the Canadian border, which were hard hit by grasshopper damage, had exhausted their funds in the previous year's efforts, and were without means to purchase supplies and labor with which to conduct the fight. In this emergency wheat growers and business men, as well as State officials, appealed to the Federal Department of Agriculture for aid. Unfortunately, no funds were available for the purpose of providing materials or labor, and, although the department summoned a grasshopper expert from the Pacific coast in order to assist in the fight, it was found that he could do little or nothing to aid the counties most in need of help. As a consequence of this condition, the spring wheat crop in several counties has been seriously reduced by grasshopper injuries. In the course of the summer's investigations it was determined that large numbers of grasshoppers were drifting northward across the Canadian border, and it is claimed that the excellent control work conducted by the Canadian Department of Agriculture was, at least in some cases, made futile by reinfestation from the American side of the line. Swarms of grasshoppers were several times seen flying from Canadian territory into the United States, although by far the heaviest flights were in the opposite direction.

The conditions as described above illustrate the great desirability of the provision by Congress of an emergency fund to be drawn on for the purpose of meeting similar emergencies in the future. The problem created by the flying of grasshopper swarms across the international border should be met by appropriate action on the part of the Governments involved and the provision of funds for this particular purpose.

Wherever funds were available for adequate control operations the results in North Dakota this year again demonstrated the efficiency of the poisoned baits as a most reliable means of grasshopper extermination, and great savings have resulted from their use.

Hessian fly.—As predicted in my last report, greatly increased damage by the Hessian fly occurred during the year throughout much of the winter-wheat belt. The injury was notably serious in Illinois, Indiana, Ohio, and southern Michigan, while damage was recorded in Kentucky, Oklahoma, North Carolina, Maryland, Virginia, and New Jersey. In Kansas conditions were much more favorable, owing, it is believed, to a vigorous campaign for control waged by State and Federal authorities during the summer of 1919. Much of the early sown wheat in Indiana and Illinois was killed out during the winter by the weakening action of the pest. A cooperative campaign for control was inaugurated by State and Federal forces during the present summer, and is being pushed vigorously in Illinois, Indiana, and Ohio, which, it is believed, will result in the protection of the winter-wheat crop of 1921 in these States. A publication giving the methods of control for Indiana was prepared by the bureau representative in that State and published as a circular of the experiment station in May of the present year. A new Federal Farmers' Bulletin (No. 1083) treating on Hessian fly control was issued in March, 1920.

Alfalfa weevil.—As a result of seven years of careful experimentation a method of spraying for the control of the alfalfa weevil

has now been perfected which it seems certain will safeguard the alfalfa crop from the inroads of this pest wherever properly applied. This method has been experimentally demonstrated in cooperation with local farm bureaus over an area aggregating some 4,000 acres in which the spraying operations were conducted by practical farmers. The average cost of the work was $1 per acre, and with alfalfa hay selling at $35 a ton it is easily seen that the cost is comparatively trifling. In one county alone local authorities estimate that the saving secured by this spraying method amounted to $40,000 for a single season. A new Farmers' Bulletin (No. 1180) describing fully the methods mentioned is in course of publication.

Chinch bugs.—Considerable damage by chinch bugs was recorded during the early summer of 1920. The work of this well-known pest resulted in more damage throughout Missouri than had occurred since 1913. Greatest injury seemed to be centered in St. Louis County, and Federal experts were active in advising farmers regarding the most efficient methods of control. Many publications were distributed in the stricken region through the cooperative efforts of State and Federal men. Illinois and other Middle Western States also suffered considerable injury.

Army worm.—Local outbreaks of the true army worm occurred during June of the present summer in Missouri and Illinois. The usual excellent control was secured wherever the poisoned bait and ditch barrier methods were used in a timely and proper manner. Department entomologists were active in giving out the required information in the infested areas. Fortunately no widespread outbreak resulted from the colonies which appeared in the States mentioned above.

STORED-PRODUCT INSECT INVESTIGATIONS.

The very great value of the work of this section of the bureau is strikingly shown in many ways. A noticeable instance occurred during the year when inspection and advice by the bureau's experts saved the Quartermaster's Department of the Navy supplies of rice and beans worth about twenty-seven times the appropriation for this project. Dr. E. A. Back continues in charge of this work.

Corn weevils.—The research laboratory established at Orlando, Fla., for the purpose of studying the biology and methods of control of corn weevils, has been continued during the year. A large amount of new information has been secured regarding the biology of weevils and their parasites. Four papers containing new information have been presented for publication and one Farmers' Bulletin (No. 1029) giving practical suggestions for farmers along the lines of corn conservation has been published and widely circulated.

The office established at Athens, Ga., has been moved to Thomasville, Ga., in order that the expert in charge may more easily reach the important corn-growing sections of southern Georgia, where an intensive campaign has been carried on to take to the farmer, in cooperation with the extension service of the Georgia Agricultural Experiment Station, information regarding the preservation of corn from weevils. This work has proved very popular and has resulted in the construction of a large number of corncribs in which corn is being successfully treated with carbon disulphid.

Bean and pea weevils.—The investigations into weevil losses to California-grown beans and peas, started during the preceding fiscal year, has been continued at the Alhambra Laboratory. The work has consisted for the most part in research work in biology and cold storage. Two papers containing original data have been submitted for publication. This work has received the hearty cooperation of the bean growers and warehousemen of the Pacific coast, and while the investigations are not yet complete, they bid fair to be of great practical value.

Control of insects in stored material.—Experimental work to determine the usefulness of fumigation, electricity, heat, and cold storage have been continued during the year with a view of lessening or preventing the enormous waste of stored goods in warehouses. Though this work has suffered through the resignation of three experts during the year, the results already obtained promise an immense saving to the country when put into operation.

Work upon the commercial machine for sterilizing cartons of cereals by means of electricity has continued during the year under private direction. It promises results of value to the producers of cereal products.

Household pests.—Investigations of household pests have taken the form largely of a dissemination of information to householders. A special study has been made of the black carpet beetle, and a paper has been prepared on this insect, giving new information. An outstanding feature of the work during the year has been the practical aid given to the Army hospitals in the suppression of pests.

Inspection and intelligence service.—The arrangement made during the war with the quartermaster of the Army at the port of New York, whereby the bureau has undertaken to make frequent inspections of food and clothing supplies, has continued to prove satisfactory, and is being extended to other depots not only of the Army but of the Navy. The purpose of this cooperation is to keep the Quartermaster Departments of the Army and Navy informed, through inspections made by bureau experts, not only of the condition of the food supplies purchased and delivered at the warehouses but also of their condition from time to time during the storage period. Such inspections detect and lead to the checking of insect ravages before the insects have had a chance to multiply and cause great loss. During the last few months the office and laboratory maintained at the Army supply base at Brooklyn, N. Y., has been closed as the result of the resignation of the expert in charge.

Temperature and humidity investigations.—During the year new research work was inaugurated to determine the effect upon insect development of varying degrees of temperature and humidity. Valuable equipment has already been secured and data new to science placed on record.

DECIDUOUS-FRUIT INSECT INVESTIGATIONS.

Investigations of deciduous-fruit insects have been carried out under the direction of Dr. A. L. Quaintance, as formerly.

The Japanese beetle.—Further experience has shown that the Japanese beetle is almost omnivorous in its feeding habits, attack-

ing many important crops, as apple, sweet cherry, grape, red clover, corn, ornamental flowers, and certain shade and forest trees; that it is an active insect and a strong flier, spreading naturally with ease, and is readily carried by artificial means; that in the absence of its natural enemies it reproduces in almost incredible numbers; that conditions in the present infested area are ideal for the insect, in consequence of which it has continued to multiply and spread in spite of restrictive measures practiced. The insect has crossed the Delaware River near Riverton, N. J., and occupies on the Pennsylvania side a strip about 7 miles long and from one-half to 1½ miles wide. Its present area of distribution is approximately 50 square miles.

The various phases of the work carried out and under way in cooperation with the New Jersey State department of agriculture may be considered under the following divisions:

Quarantine.—A quarantine against the Japanese beetle was inaugurated in 1919 and included only sweet or green corn. Further experience indicated the necessity of extending the quarantine to all other farm crops, as well as nursery and greenhouse products, and such a quarantine is established and in successful operation at the present time. As a necessary basis for establishing quarantine areas, we have thoroughly scouted the territory to keep track of further spread. Much attention has been given to this scouting work, and the distribution of the beetle from week to week is pretty accurately known.

Control.—Increased funds permitted much more effective control operations than previously. To restrict the spread of the beetles attempt has been made to maintain a barrier band of dusted or sprayed foliage about a mile wide completely around the infested area. Within this band all food plants on headlands, along roadways, and elsewhere have been eliminated as thoroughly as possible. Despite effective work in keeping the barrier band well coated with repellents and poisons, indications are that the beetle will not be held by it, but will continue to spread.

Within the infested area we have encouraged the residents to adopt farm practices to destroy the insect in the grub stage. Systematic collection of beetles by hand has been followed, and great numbers have been destroyed. Much work has been done to destroy the grubs in the soil by the application of soil insecticides in the worst infested areas. Headlands and roadways have been kept as clear as possible of food plants by destruction with weed-killing chemicals, by fire and other means. This work is of considerable importance in minimizing the chances of distribution of the beetles on passing vehicles, by pedestrians, and otherwise.

Investigation.—Preliminary insecticide investigations were begun early. During the year just closed this work has been materially strengthened and a very large number of materials likely to be repellent or poisonous have been experimented with. Tests have been made with a large series of chemicals likely to prove attractive to the insects, and other lines of inquiry were followed. In consequence of the quarantine it became desirable to ascertain whether plants with earth balled around the roots could be so treated as to destroy any grubs present, and many experiments were made.

Introduction of natural enemies.—An experienced entomologist is now in Japan studying the natural enemies of the beetle, and it is

hoped that parasites or other natural enemies can be introduced and established in New Jersey. One sending from Japan of a predatory beetle has already been received.

Peach insect investigations.—Investigations of peach insects have been continued in Georgia, Mississippi, and Arkansas. Peach growers in Georgia last year suffered very heavy losses from the combined injuries of the plum curculio and brown-rot, which were notably more prevalent than in previous years. During the growing season of 1920, the curculio has been even more destructive, causing a heavy loss estimated conservatively at about $2,000,000 for the State. Unusual weather conditions and other factors have so increased the abundance of this pest that treatments effective in its control during normal times were quite ineffective under the conditions which prevailed. There is some evidence that in the presence of abundant rains and high temperatures the curculio may develop a partial second brood of larvæ which infest the ripening fruit, causing an increased proportion of wormy fruit at harvest time. The inconspicuous character of the curculio egg punctures on the peach makes it difficult to detect infested fruit, and undesirable quantities may be gathered and shipped to the market in spite of the best efforts of the growers. The importance of the situation warrants a careful reinvestigation of the whole subject of curculio control in peach orchards in the South.

The work in Mississippi has been continued under more favorable conditions and the data obtained confirm previous conclusions that under average weather conditions dusting of trees with insecticides and fungicides is as effective in the control of the curculio as spraying. Large-scale experiments have been undertaken with arsenicals in the post-harvest treatment to destroy the curculio during the period over which they are supposed to be feeding in orchards and before they enter hibernation. The curculio population in treated and untreated blocks is ascertained by systematic jarring operations, taking records of the beetles caught.

Further experience with para-dichlorobenzene as a treatment for the peach borer indicates the effectiveness and safety of this treatment for this very serious pest. The use of this material is now being adopted by numerous orchardists, and no failures have been reported. In Arkansas an orchard of about 200 acres was treated last fall with para-dichlorobenzene, and large purchases of the chemical have been made for use in Georgia and other peach-growing districts during the fall of 1920.

Apple insect investigations.—*Codling moth.*—Life-history studies of the codling moth have been continued about as described in the last report, though work was undertaken in one new locality, namely, northern Georgia, to ascertain the number of generations and other life-history facts relative to the insect in this southern locality. The work on the codling moth in Colorado has been completed, and reports on life history and on experimental work in orchards are now in the course of publication. Information has been obtained on the effect of low temperatures on the insect; thus the winter of 1919–20 in the Rogue River Valley was the coldest in the history of the local station. This spring a large percentage of overwintering larvæ was found dead. The same experience was observed at Yakima, Wash.

Continued tests with the spray gun in orchards indicate its value as a permanent appliance in orchard spraying. When carefully compared with spray rods and nozzles there appears to be little difference in effectiveness, with a distinct advantage for the spray gun in rapidity of application. At the Delaware station attention has been given to the influence of packing sheds on the abundance of the codling moth; thus, in cooperation with several prominent apple growers, baskets used to harvest the apple crop of 1919 were kept over winter and spring in tight buildings. During the period of spring emergence of the moth hundreds of them appeared from cocoons spun in the baskets, but died in the buildings instead of escaping in the orchards as they do in most instances. This factor in codling-moth control is one that has not been sufficiently stressed, especially in view of the increase of packing houses in orchards. It will receive further attention.

Experiments are under way to establish, if possible, in the Yakima Valley certain eastern parasites of the codling moth, which are here of considerable value. Some shipments have already been made. In cooperation with the Connecticut Agricultural Experiment Station and certain other northeastern institutions, tests are being made with a three-in-one dust composed of a fungicide, arsenate of lead, and tobacco extract for the treatment at one and the same time of fungus diseases, biting insects, such as the codling moth, and sucking insects, such as plant-lice and red bugs.

In connection with studies of the codling moth, attention is also being given to numerous other apple insects, and valuable data have been accumulated on the life histories and the effect of various control measures. Among these are the apple maggot, cankerworms, certain leafhoppers, the apple curculio, etc.

Work with apple-tree borers which has been under way for some time is now nearing completion and publications have been issued or are in press.

Grape insect investigations.—The investigations of the insect pests of the grape in northern Ohio have been continued in cooperation with the Ohio Agricultural Experiment Station, particular attention being given to the grape-berry moth. Additional data have been obtained on its life history and further experiments have been carried out in vineyards. Experience with the two-spray method of control confirms earlier conclusions that this plan is effective in preventing serious injury and in obviating almost entirely the presence of spray residue on the fruit at harvest time. Results obtained from a single spray confirm earlier results and indicate that in vineyards where the grape-berry moth is not seriously destructive one treatment with an arsenical, such as arsenate of lead, will be sufficient.

Complaint was received of the destructive occurrence in portions of the grape regions of Michigan of the grape rootworm and a species of plant-louse. Although these pests have long been present in this territory, their injuries there have heretofore been quite unimportant.

Miscellaneous grape insects in the Ozarks.—In connection with the bureau's laboratory at Bentonville, Ark., attention is being given to grape insects in the Ozark region of Arkansas and southern Missouri, in the latter State, in cooperation with the Missouri Fruit Ex-

periment Station. The life histories of the principal insect enemies of the grape are being investigated and remedial work is under way.

The development of a satisfactory means of control of the grape mealybug in California still engages the attention of an agent at Fresno. Further work with sulphur fumes as a treatment for this insect during the dormant period of the vines indicates that this is not a practical plan, and other methods are under investigation.

The white-lined sphinx moth occurred this year in several sections of Tulare and Kern Counties, Calif., in young vineyards. From all indications the caterpillars had been feeding in near-by grain and grass lands, and as soon as these were harvested or dried up they migrated to the young green vines. Several sprays were tried with but little success, as the insects were nearly full grown when discovered, though it was found that the insects could be collected readily by hand, one man being able to cover as much as 12 acres per day. The Achemon sphinx moth was also in evidence in Merced County, injury beginning about the 1st of June. About 1,200 acres were involved, and in view of the expense of spraying, the vines were dusted early in the mornings with a dust composed of 3 parts of sulphur to 1 part of arsenate of lead. This proved to be very effective, most of the insects dying within 24 hours.

Cranberry insects.—The investigations of cranberry insects in Washington State in cooperation with the Washington Agricultural Experiment Station were concluded at the end of the growing season of 1919 and a report has been prepared. Very satisfactory results were secured in the treatment of the blackhead fireworm by three applications at intervals of 17 to 21 days between May 1 and July 17 of nicotine sulphate containing 40 per cent nicotine used at the rate of 1 part to 800 parts of spray, with the addition of fish-oil soap at the rate of 2 pounds to each 50 gallons of the liquid. Growers generally have adopted the treatment indicated and are securing satisfactory results in the control of this, their principal insect pest.

Nut insect investigations.—*Pecan insects.*—Further experiments in orchards have shown that the pecan-leaf case-bearer is best controlled by a spray of arsenate of lead, as compared with an application of this arsenical in dust form; in fact, none of the various dusts were very satisfactory. It also develops that in the use of calcium arsenate in dust or liquid form considerable burning of foliage and of nuts resulted. It was found that the so-called obscure scale, frequently complained of on pecan, can be controlled by spraying with either crude-oil emulsion or lime-sulphur solution in winter strength applied during early spring before the trees bud out. Spraying and dusting experiments in the control of the pecan weevil were unsuccessful. On the other hand, fumigation of harvested nuts with carbon disulphid at the rate of one-half ounce of the fumigant per bushel of nuts, with an exposure of 24 hours, proved effective. This method is only partially successful, however, since a considerable portion of the larvæ in some regions leave the pecans before harvest time. A report on the pecan nut case-bearer, embodying information on its life history and control measures in the Southeast, has been completed. A publication on the pecan bud-moth is in preparation.

The investigations of pecan insects in the Southeast having been fairly well completed, it seemed desirable to transfer the work in the Southeast to Texas, which was done in June. Special attention in that State will be given to the pecan nut case-bearer, which is there very destructive, and also to the pecan weevil and other miscellaneous pecan insects.

Miscellaneous nut insects in the North.—The walnut husk maggot, which fed originally and still feeds extensively in the husks of black walnuts, is now attacking the husks of Persian and Japanese walnuts in the eastern part of the country. The maggots in great numbers mine through the husks, causing the nuts either to drop prematurely or to adhere to the branches beyond the regular harvest time. The shells of the nuts are also stained and soiled by the maggots. In several localities in Maryland and Pennsylvania very promising crops of Persian walnuts have been practically ruined by this species. A study of the life history, habits, and means of control of the husk maggot is under way and results will be ready for publication by the end of the season.

Several species of walnut and hickory curculios are also under investigation. These insects attack the immature nuts, causing many of them to fall. The walnut curculio attacks butternuts, Persian walnuts, and Japanese walnuts, causing the nuts to drop prematurely, and the grubs mine the tender shoots of the husks, frequently killing young trees. Another form, *Conotrachelus retentus*, lays its eggs in black walnuts when the nuts are about one-fourth grown, the larvæ causing the nuts to drop. By actual count it has been ascertained that in some localities from 50 to 90 per cent of the nuts are infested. The weevils attacking chestnut and hazelnut are also being studied. Choice varieties of our native hazel are being introduced by nurserymen and the present interest in growing hazelnuts makes a study of the hazelnut weevil important.

Orchard insecticide investigations.—Investigations of miscellaneous insecticides have been continued. A comparative study of arsenicals as insecticides, in cooperation with the Bureau of Chemistry, has been under way during the past two or three seasons and includes a study of raw materials, methods of manufacture, analyses and classifications and physical properties of arsenicals, relative toxicity, amount of arsenic required to kill insects, and relation of soluble arsenic before being eaten and after being eaten by insects. This work has involved a very large amount of detail, requiring the feeding and examination of thousands of insects and careful recording of the actions of food. It appears that the percentage of water-soluble arsenic in the arsenicals before they are eaten by insects has little to do with the toxicity of these arsenicals, although with regard to those arsenicals in which the arsenic content is nearly all water-soluble the rate of toxicity is generally highest. As a rule, also, the higher the percentage of arsenic rendered soluble inside the bodies of insects, the higher is the rate of toxicity, and furthermore the more arsenic retained inside of the insects as compared with that voided in the feces, the higher is the rate of toxicity. Evidently only an indefinite opinion concerning the killing power of an arsenical can be inferred from its composition, but judging from both the chemical and insecticidal results obtained the toxicity depends directly upon

the amount of arsenic rendered soluble inside of the insects, and this solubility depends directly upon the stability of the compound. These comparative studies of arsenicals as insecticides are now nearing completion, and a report will be prepared at the close of the present season. Much experimental work has been accomplished with contact insecticides in an effort to find something to replace nicotine or tobacco extract. These studies have included testing of various fractions of mineral oils and a very large list of miscellaneous chemicals. In cooperation with the Bureau of Chemistry special attention has been given to organic contact insecticides and a compound has been discovered of the pyridine series which offers hope of success. Much work has also been accomplished in a study of the vitamines in insect nutrition as bearing on the food requirements and choice of food of insects. In addition to the foregoing investigational work the usual amount of testing proprietary and other insecticides in orchards has been conducted to keep the office informed on the merits of these as they appear from year to year.

VEGETABLE AND TRUCK CROP INSECT INVESTIGATIONS.

Investigations of the insects affecting vegetable and truck crops have been carried on under the direction of Dr. F. H. Chittenden, as heretofore.

Sweet-potato weevil eradication and control.—Intensive work on this project has been continued, although handicapped by a shortage of funds. Since the infested area, comprising portions of six States, was well determined during the preceding year, efforts were restricted to actual eradication and to investigational work. In Florida very favorable results have been secured by cooperative clean-up measures with the farmers. This work has been closely followed by the inspectors, and where proper cooperation had not been shown by the farmers themselves, all old banks were burned and volunteer plants pulled from old fields. A close reinspection has been continued over the infested area. It is gratifying that no infestations outside of the original area have been found, 401 farms being under continual supervision. In cooperation with the State Plant Board of Florida, about a million weevil-free draws were distributed to 214 farms previously infested. It appears that the infested area in Florida and Georgia has been materially reduced and that marketable crops are being produced where three years ago sweet potatoes were annually rendered useless through weevil attack.

In Alabama 30 farms in a well-circumscribed locality were found to be infested, and careful clean-up measures were carried out, with the result that our inspectors have been unable to find a single weevil during the harvesting and planting season this year. It is accordingly believed that Alabama may now be declared weevil free. This will, however, be determined by a thorough inspection of the coming harvest.

In Mississippi activity has been similar to that in the more eastern States. Two hundred and thirty-two infested farms now remain. All of these were planted with weevil-free draws during the past spring, and it is at present impossible to judge definitely as to the actual reduction in infestation. Nearly one and one-half million

weevil-free draws were distributed in this territory. The indications are that a material reduction, both in the number of farms infested and in the seriousness of infestation, may be expected.

In Louisiana, owing to the extent of infestation and the absence of satisfactory legislation, eradication has not been attempted. A test is, however, being made of the application of approved cultural methods by interested growers in one of the more seriously infested localities. A high grade of neighborhood cooperation having been secured, it is expected that a material saving will result from the adoption of the processes recommended. Even though strict eradication measures have not been applied in the selected locality, work has been continued on the experimental eradication of wild food plants.

In Texas large-scale control projects and life-history work have been begun. More than 8,000 specimens have been carried separately through all stages possible.

In general, it may be mentioned that a weevil-free zone 30 miles in length is being maintained on the eastern coast of Florida through the destruction of the seaside morning glory, and that the only infested plot of this wild food plant on the mainland of Mississippi has likewise been destroyed. Preliminary or progress reports on the habits, life history, control, and eradication of this pest are in preparation and will soon be available for publication.

Insects affecting potato, tomato, and allied crops.—The Colorado potato beetle has been the subject of investigation with especial reference to its scarcity in recent years in Maryland and Virginia. Late spraying, parasitism, and severe winter weather are powerful elements in holding this pest in check. Continued investigations of this problem are desirable. The potato leafhopper, which causes a condition known as "leaf burn" or "hopper burn" to potatoes in the potato-growing sections of the Northern States, is being carefully studied, especially in Wisconsin. Bordeaux mixture has proved a satisfactory repellent, while nicotine sulphate and kerosene emulsion, standard remedies for sucking insects, have been found ineffective. The tarnished plant-bug has been investigated to determine especially all of its wild food plants and breeding plants, a project of economic value requiring careful study in its extensive range. It has been the cause of severe injury to potatoes in some sections and has undoubtedly caused other damage without the source being known. Study of the spinach aphis and the potato aphis, important enemies of these crops, has continued.

Insects affecting beans and peas.—Injury by the bean ladybird in Colorado and New Mexico has continued with the exception of points where its control by spraying through the use of methods developed by this bureau has been adopted. A practically complete account of this insect in its western occurrence, in addition to an emergency Farmers' Bulletin (No. 1074), has been published. A threatening outbreak of this insect, the first of record east of the Rocky Mountain States, has just been reported from Jefferson and Bibb Counties, in Alabama, indicating that it is likely to become permanently and extensively established east of the Mississippi River. Since it will probably become as costly a pest on beans and cowpeas as is the Colorado potato beetle to potatoes, immediate action should be taken to effect its eradication.

There has been an unprecedented outbreak of the green clover worm over the eastern United States, particularly along the Atlantic seaboard, many fields of all varieties of beans being practically defoliated. This pest was found to be controlled readily on truck plantings by the application of suitable arsenicals. Studies of the pea aphis on the Pacific coast are being continued. The pea moth, recently introduced into the Northern States from Canada, has been studied, and it has been determined that it is not of European origin, as formerly believed, but new to science.

Cucurbit insects.—Although a practical treatise on the striped cucumber beetle and its control is available in the shape of a Farmers' Bulletin (No. 1038) recently issued, the insect is a difficult one to control and constant work is being done on it, especially in its rôle as a carrier of a cucurbit disease, in an endeavor to discover more effective methods for holding it in check. Certain repellents and poisons were tested during the year but found to be without value. The Bordeaux arsenate of lead mixture combined with other measures has proved the best means for its control. Work on such important pests as the melon aphis, the squash bug, and the squash vine-borer has been continued and results of an investigation of the squash bug are available for publication.

Insects injurious to cabbage and allied plants.—Extensive experiments have been under way on the Pacific coast against aphids affecting cabbage and other crops with the newly devised nicotine dust spray as a contact insecticide. A monographic account of the western cabbage flea-beetle, a pest of great importance west of the Mississippi River, has been completed and is available for distribution. Much attention has also been given to the study of the life history and habits of the other injurious flea-beetles which affect cabbage, turnip, and related crops. The false cabbage aphis was the cause of a severe outbreak on turnip, kale, and seedling cabbage in early spring in Maryland and Virginia. The attack was of such suddenness and severity that it could not be checked, and it ceased before control experiments could be completed. Preliminary work on the European horseradish webworm, which has been a pest for a number of years in Canada, has been carried on, especially in reference to its recent occurrence in Virginia, and similar preliminary work is being done on some other insect enemies of horseradish.

Sugar-beet insects.—Work on the sugar-beet leafhopper, which causes the costly condition known as "curly top," has been continued. The nature of the disease and the importance of temperature, number of insects, length of feeding time, and other factors in its production are being investigated. It has been found that an interesting alternation of food plants, involving at least two wild species, occurs between the production of disease on sugar beets and reinoculation. Three hundred and fifty types of resistant beets selected from various California fields are being studied. The work at Greeley, Colo., involving the control of the webworms injurious to the sugar beet and investigations of the beet root-aphis, has been temporarily abandoned, owing to a reduction of appropriations. It is reported that serious injury to beet fields in eastern Colorado has resulted from lack of instruction as to control measures for the sugar-

beet and so-called alfalfa webworms. A comprehensive account of the beet leaf-beetle, an important enemy of beets of all kinds in the Western States, has been completed. This insect has practically the same distribution as the bean ladybird but appears to be decreasing in injuriousness.

Other truck-crop insects.—A new enemy to strawberries, recently discovered in Virginia, an imported moth which works as a crown borer, is being investigated to determine its capabilities as a pest. Other insect enemies of strawberry, blackberry, and raspberry, especially the strawberry weevil and the leaf-rollers, have been studied, and accounts of some of the more important forms are available for publication. The minor insect enemies of the sweet potato have been the subject of similar investigation. The onion maggot has been under continual investigation in the hope that some more practical and inexpensive remedy than is now known may be discovered.

INVESTIGATIONS OF INSECTS AFFECTING FOREST RESOURCES.

The work of the Branch of Forest Entomology has been continued, as before, under the supervision of Dr. A. D. Hopkins.

In addition to the investigation of insects affecting the forest resources of the country, the allied subject of shade trees and ornamental shrubs received some attention. While the forest resources represent an indispensable need of the Nation and are an item of pecuniary wealth, the shade trees and ornamental plantings of parks and streets, grounds of health and pleasure resorts, public institutions, and city, suburban, country, and farm homes represent a form of wealth which the people realize in health, recreation, enjoyment of the home, and increased value of property.

Principal depredations of the year.—In addition to the usual damage by insects to forest and shade trees and forest products, which amounts, in reduced values and direct losses, to more than $100,000,000 annually, there has been no conspicuous increase in the more destructive insects except that of the spruce budworm in the spruce forests of northern New England, which has been the source of considerable alarm to the manufacturers of paper pulp and the publishers of newspapers; a defoliating worm affecting large areas of pine in Texas; and a threatened outbreak of the southern pine beetle, which is the worst menace to the pine forests of the Southern States. The defoliation of the Sitka spruce of the Oregon and Sitka coasts by plant-lice and caterpillars has been the subject of special inquiry. The dying of elms in the Mississippi Valley and of oaks in the Southern States has attracted much attention, and there has been a decided increase in the requests for information about insect damage to shade trees. One of the most remarkable losses of a serious nature has been that caused by a wood-boring beetle to lead telephone cables in California. Damage by wood-boring insects to ash lumber for the manufacture of aircraft at the Philadelphia navy yards was the subject of investigation and recommendation. Sixty-eight cases of damage by white ants or termites to buildings and contents were reported from 21 States, 3 Territories, and the District of Columbia. Some of the notable examples in Washington City were damage to and in the new Bureau of Engraving and

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Printing, where Government bond paper and postage stamps were destroyed; damage to the woodwork of one of the new buildings at the Soldiers' Home; continued damage to the floors of the old National Museum building and to stored material; damage to the greenhouses and plants of the War Department and to the dwelling of the Secretary of War. Serious damage to fruit trees and vegetable crops by these insects was reported from California.

The damage to crude forest products by wood-boring insects continues to cause extensive losses throughout the forested sections of the country where logging operations are carried on.

Principal lines of investigation and results.—The principal lines of investigation carried on during the year have included the continuation of an intensive study of the character and extent of the damage caused by tree-killing barkbeetles and methods of controlling them in some of the principal national and private forests of the Pacific slope and Rocky Mountain regions.

In southern Oregon a study was made of the causes of the natural increase and decrease of the western pine beetle, including records on 2,549 trees, representing a volume of over 2,000,000 board feet. It was found that the average killed tree was attacked by 2,070 beetles, which deposited over 74,000 eggs in the bark, but that only about 30 per cent of these developed to the beetle stage. It was also found that out of the number of beetles that develop in and emerge from the trees killed by them, only about 3 per cent survive to continue the attack on other trees. This furnishes important evidence as to why the percentage principle of control is successful, for this 3 per cent survival is still further reduced in attacks that fail and by natural enemies and other natural causes until there is a much smaller percentage to congregate in sufficient force to continue the killing of trees. Thus in artificial control, by which a sufficient percentage of the killed trees are treated to reduce the numbers of the beetles below their power of concentration in sufficient force to overcome the natural resistance of the living trees, the beetles cease to be a menace and the problem is solved.

Inspections during May, 1920, of the area in the Middle Fork basin of the Sequoia National Park, where control work was conducted by the National Park Service, the Forest Service, and the Bureau of Entomology, showed that, while 1,055,000 board feet of yellow pine and sugar pine timber had been killed by beetles in 1917, the treatment of 52 per cent of the volume of the infestation in 1918 was followed by a decline of 71 per cent in the total loss of the preceding year. In the yellow pine alone 60 per cent of the infestation was treated and the subsequent decline amounted to 81 per cent.

Experimental trap tree work was carried on during the summers of 1919 and 1920 in the Marble Fork and Cactus Creek Basins of the Sequoia National Park at a cost of $500. As a result both basins are now free from evidence of any serious infestation.

A detailed study of the character and extent of depredations by tree-killing beetles in the pine forests of California, as represented by Federal Forest District 5, shows that during one year, 1917, approximately 90,000,000 board feet of yellow pine and sugar pine were killed by the western pine beetle and mountain pine beetle.

This represents a stumpage value of $270,000. It is estimated by forest officials and representatives of the Bureau of Entomology, who are in a position to have intimate knowledge of the subject, that this amount represents the average annual loss during seven years, 1912–1919, which would represent a loss of 270,000,000 board feet of merchantable timber with a stumpage value of $2,340,000. During this period, owing to lack of funds, it was possible for the Forest Service to expend but $60,000 toward the prevention of this great loss of forest resources. Through a completely organized cooperative arrangement between the Forest Service and Bureau of Entomology, 130,000 acres within the San Joaquin drainage in California, with a stand of 1,507,500,000 board feet of yellow pine and 682,500,000 board feet of sugar pine, were covered by control work in 1920, and the work of maintaining control will be continued during a period of five years. One of the objects of this project is to make a thorough test of the percentage principle and other methods of control that are recommended by the Bureau of Entomology. An area of 24,000 acres will be left without treatment to serve as a basis of comparison with the treated area.

The application of the newly-discovered "Craighead solar heat principle" of insect control, in connection with work against the western pine beetle in California, has shown that a maximum daily temperature as low as 75° F. during a few clear days will kill the broods of beetles in the infested bark removed from the trees and exposed to the direct rays of the sun. This method renders it possible to continue control work during the summer months which heretofore could not be done by the method of burning the bark owing to fire hazard.

Extensive reconnaissance and intensive studies are being made in the Coeur d'Aléne National Forest of northern Idaho, where, in 1913, over 4,000,000 board feet of merchantable white pine timber was killed by the mountain pine beetle. The area to be covered by the investigations is over 348,000 acres, including 80,000 acres of yellow pine, with smaller areas amounting to 5,000 acres for the intensive studies.

The extensive experiments conducted at our field station in southern Arizona during the last five years, to determine the time of year to cut mesquite for fuel and other required local products to avoid destruction of the wood by insects, have been completed and the fact has been demonstrated that if mesquite is cut for cordwood, posts, etc., between October 15 and January 15 in southern Arizona and piled in open ricks, little or no damage will be caused by insects. This result is of great economic importance to the residents of all sections of this and other countries where mesquite furnishes the only or principal source of fuel and wood products, because ordinarily, under the common practice of cutting in the spring and summer months, a very large percentage of the wood is converted into piles of boring dust before the end of the summer.

The solar heat principle of preventing insect damage to mesquite posts was found to be entirely successful. The posts were cut and put out in the sun and turned occasionally until the bark was thoroughly dried. This kills the insects that get in before the bark

is dry, and the dry bark is not attacked by insects which are destructive to the wood. This makes it practicable to cut the trees any time during the summer.

The lead cable borer.—Studies and experiments at our field station at Los Gatos, Calif., and East Falls Church, Va., relative to damage to lead telephone cables by a wood-boring beetle have been continued with prospects of solving the problem. The telephone companies have furnished a large amount of material and gone to considerable expense to offer facilities for the investigations.

Chemical treatments of wood.—Experiments in chemical treatments of commercial wood products to prevent insect damage have been continued, and the results so far indicate that a number of kinds of North American woods can be treated so they may be safely used in tropical countries, where otherwise serious damage would be caused by termites.

Water submergence and sun-curing treatment of crude products.—Experiments during the year have shown that a combination of water submergence and sun curing will prevent injury by wood-boring insects to saw logs that must be held over during the spring and summer months.

Seasonal cutting.—The extensive experiments in seasonal cutting of timber to determine the best time to do the work have been completed, and the results show that there are optimum times for the cutting of different species of trees to avoid insect damage to the bark and wood. This is of especial importance in connection with material for log houses and rustic work.

The host selection principle.—Continued experiments relative to the Hopkins host selection principle tend to establish the fact that insects which attack a number of species of trees or plants prefer to continue their attack on the particular species in which they have bred for a few seasons. This knowledge is of special economic importance in connection with control work against certain insects.

Shade trees.—The work on insects affecting shade trees and ornamental hardy shrubs has been limited largely to correspondence, owing to the lack of funds to be devoted to this line of work. There is a constantly increasing demand for information on the subject, and some special investigations have been conducted at field stations at Los Gatos, Calif., and Colorado Springs, Colo. There is urgent need of the extension of this work.

The bioclimatic law.—Much time during the year has been devoted by Dr. Hopkins to the continuation of investigations relative to the application of the principles of his bioclimatic law to entomological and agricultural research and economic practice, in which notable progress has been made toward establishing the principles involved and the development of systems of applying them in the solving of problems of utmost importance to human interests.

Recent studies have shown that the law applies to the continental areas of the Northern and Southern Hemispheres, and that it gives a reliable basis for the classification of the major and minor zones of the world in which similar conditions of climate and life may be expected to occur, thus giving a new basis for a more scientific consideration of the problem of the introduction of useful plants and animals and the prevention of the introduction of pests from

one country to regions and sections of another country where the conditions are most favorable for their establishment.

General results.—Under the head of general results as related to the pecuniary value to the country of the investigations of insects affecting forest resources, it is significant that wherever control operations have been carried on during the last 15 years in forested areas of the Rocky Mountain, Pacific Slope, and Southern States, principally in the national forests and parks, notable reductions in the dying of the timber followed in each case, and that up to the present time comparatively little timber has died within the areas where only a very small percentage of the original infestation was disposed of.

It has been frequently stated by Dr. Hopkins that it was his belief that if a general and serious and continued effort was made to apply the information that has been disseminated on methods of controlling the principal tree-killing beetles, it would be but a few years until these worst insect enemies of North American forests would be brought under complete control and ultimately they would become rare and require little if any attention. The conditions prevailing at present throughout extensive areas where only a comparatively little control work has been done seem to give good support to the idea.

The management principle.—Another striking example of the results of investigations and the dissemination of information is the general decrease in the formerly extensive losses of seasoned hardwood products from damage and destruction by powder-post beetles, not as the result of the application of expensive remedies but of the inexpensive and often better methods of management in the storage, inspection, and use of the material that was advised.

Other changes that have been advised and adopted in the methods of handling and manufacturing of crude forest products and in the general management of public and private forests with little or no additional expense show that the management principle of preventing losses from insects is of fundamental importance.

In connection with the principle of adjusted management to provide against losses from insects and otherwise to secure the best results from energy and money expended, it is found that a knowledge of the laws which govern life and climate will suggest innumerable methods of procedure in combating farm pests, especially in the selection of the optimum time to plant to avoid or lessen insect damage (as in the case of the Hessian fly) and otherwise secure the best results. The adjustments of crops and types of farming to local and regional climatic requirements are among the things which would contribute to the prevention of serious losses and to increased production.

Estimates of values and losses.—Estimates based on accumulated data from various sources indicate that the Nation's wealth in forest resources and in shade trees and ornamental shrubbery is not less than $10,000,000,000 and that the direct and indirect depreciations and losses caused by insects annually to this source of wealth and human welfare represent a money value of 1 per cent, or not less than $100,000,000.

WORK ON THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

Work on this project has been continued under the supervision of A. F. Burgess, with headquarters at Melrose Highlands, Mass.

During the spring of 1919 the egg clusters of the gipsy moth hatched almost perfectly, there having been practically no mortality during the previous winter, which was very mild. This fact, combined with the unusual prevalence of high temperatures and favorable air currents during the hatching period, resulted in an unusual spread of the insect in the young caterpillar stage.

Scouting work, which was carried on during the winter, indicated a much larger area infested, particularly in Maine, New Hampshire, and Vermont, than has ever been reported heretofore. A number of additional towns near the northern part of the infested border line in Massachusetts were also found to be infested. Along the balance of the border in southern Massachusetts and Connecticut only a slight increase in the infested area occurred. Winter conditions in New England were particularly severe, there being unusually low temperatures and very deep snow. This interfered materially with the progress of the work of determining the condition of the infestation, and this factor, coupled with the increase in cost of labor and supplies, prevented a large amount of necessary work from being done.

The increase in area found infested during the past year amounts to 4,569 square miles, 1,392 square miles being in Maine, 1,921 square miles in New Hampshire, 824 square miles in Vermont, 371 square miles in Massachusetts, and 61 square miles in Connecticut. These areas were added to the quarantined area in New England, and products shipped from them that are likely to carry infestations must be inspected before they are allowed to proceed. The quarantined area now includes 25,316 square miles.

A reinspection of the old colony sites in New York, Ohio, New Jersey, and the western part of Massachusetts failed to indicate the presence of the insect, and it is very reasonable to believe that these colonies have been exterminated.

The area infested with the brown-tail moth has been materially reduced during the year and 10,677 square miles have been eliminated from the quarantine—8,492 square miles in Maine, 711 square miles in New Hampshire, 714 square miles in Massachusetts, 29 square miles in Rhode Island, and 731 square miles in Connecticut. The quarantined area now amounts to 18,075 square miles.

Field-control work.—Scouting of the border area indicated many small gipsy moth infestations in towns outside those under quarantine. In spite of unfavorable weather and scarcity of men, scouting and clean-up work was carried on in 255 towns, distributed as follows: Maine, 89; New Hampshire, 81; Massachusetts, 39; Vermont, 28; Connecticut, 17; and Rhode Island, 1. In addition to this, scouting was carried on in the outside colonies in the other States previously mentioned. During the progress of the scouting work, over 7,800 miles of roads were examined, as well as large areas of orchard, pasture, and ornamental trees and shrubbery.

During the early spring gipsy moth banding material was applied to trees in 29 towns in New Hampshire, Vermont, and Massachu-

setts—11,187 bands being used. Spraying operations were considerably interfered with by an unusual amount of rainfall during the month of June. Two horse-drawn spraying machines were converted into motor-propelled outfits so that there were available for the season's work 14 motor-truck sprayers and 5 horse-drawn machines.

Considerable difficulty was experienced in securing prompt delivery of arsenate of lead, owing to strikes and freight embargoes, but as the season was later than usual, resulting in delayed pupation of the caterpillars, it was possible to carry on spraying work satisfactorily during the first week in July. This, in part, compensated for the difficulties encountered in the early part of the spraying season, although the treatment is most effective if applied as soon as possible after the caterpillars have hatched. The machines were distributed along the border of the infested area in New Hampshire and Massachusetts and one sprayer was assigned to work in Rhode Island. The spraying in Connecticut was done with the equipment of the State entomologist and by the men in his employ. During the season, spraying work was carried on in 22 towns, and 3,617 acres were treated. In addition to this, 14,954 trees growing in orchards and pastures or on private grounds were sprayed.

Experimental work.—The extremely severe winter of 1919 resulted in heavy mortality of gipsy-moth egg clusters over a large part of the infested area. Along the seacoast and in the southern part of the area this condition did not exist, except to a moderate degree. Eggs of the gipsy moth that were deposited near the ground, where they were protected by snow, which was unusually heavy during the winter, hatched in a normal manner. Extensive experiments indicate that a temperature of 20° or more below zero is fatal to most of the eggs in the cluster. In case they are protected by snow or other means, this rule does not hold good.

Egg parasitism by *Anastatus bifasciatus* has been very satisfactory in many localities during the past season. The maximum destroyed by this insect, however, is rarely over 50 per cent of the eggs in the clusters, so that the gipsy moth can not be controlled completely by this insect. This parasite spreads very slowly and there are infested areas in the deep woodlands where the species has not yet become established. During the year 1,220,000 specimens were liberated, principally in woodland areas in New Hampshire.

In the fall of 1919 *Schedius kuvanae*, another egg parasite, was found more abundantly than during the previous year. It is particularly susceptible to low temperature during the winter and its numbers were very greatly reduced as a result of the severe winter of 1919. Five hundred and forty thousand were colonized in eastern New Hampshire in the fall of 1919. Colonization of these two species was made possible by assistance rendered by the State entomologist of New Hampshire.

Compsilura concinnata, a tachinid fly, occurred in about the same degree of abundance as during the previous year. High parasitism was noted, however, in many of the small isolated colonies, and in one locality under close observation in Melrose the destruction of gipsy-moth caterpillars by this insect was very much higher than usual.

Blepharipa scutellata, another tachinid parasite which kills gipsy-moth caterpillars at the time of or just after pupation, was collected more abundantly than last year. Over 65 sample collections from representative localities covering the entire infested area were found to be parasitized to a greater or less extent. In one of these collections the entire lot was destroyed by this insect.

A very striking case of parasitism was found in large collections of gipsy-moth pupæ made in the vicinity of Franklin, N. H. In a single lot of 7,000 pupæ 94 per cent were destroyed by this agency. The insect is now distributed over the greater part of the infested area, and even greater results are anticipated from its presence.

Improvements have been made in the methods of breeding and colonizing *Apanteles melanoscelis*. During the year 22 colonies, containing 11,000 individuals, were liberated. During midsummer the cocoons of this parasite were found in large numbers in locations where it had been previously colonized, and the results from this species during the past year have been very encouraging. Apparently this insect has not yet increased to the point of giving maximum efficiency. *Calosoma sycophanta* is more abundant this year than usual, and many reports have been received from citizens living in the infested area confirming the value of this beetle as an enemy to the gipsy moth. The wilt disease has been reported from more localities than during the previous year..

The area infested by the brown-tail moth has been reduced during the past year, but several bad colonies have been found in the eastern part of Massachusetts and in New Hampshire. A number of cases of severe defoliation to orchard trees resulted and for the first time for several years the moths were taken in small numbers at electric arc lights.

Parasitism of this insect by *Zygobothria nidicola* was about one-half that recorded during the previous year, although there was considerable local variation in the abundance of this parasite.

Parasitism of the brown-tail moth by *Apanteles lacteicolor* and *Meteorus versicolor* was considerably less than in past years. In a single bad colony of the brown-tail moth at Burlington, Mass., the fungus disease *Empusa aulicae* was present and caused the destruction of large numbers of caterpillars.

A study of the parasitism of native caterpillars has been continued throughout the year and much valuable information secured. During the winter, however, unusually high mortality resulted to the material in hibernation. This work has emphasized the value of Compsilura as a parasite on many of our common caterpillars.

Quarantine work.—During the year 33,125 shipments have been inspected and certified and 331 permits have been issued for material to be shipped from the gipsy-moth infested area to points outside. The greater part of the shipments consisted of quarry products, nursery stock, and forest products. Evergreens, such as Christmas trees and miscellaneous material, were also included. More than twice as many Christmas trees and evergreens were shipped than during the previous year.

On July 3, 1920, notification was received that a severe colony of the gipsy moth had been found in Somerville, N. J., and a few days following the insect was reported in Brooklyn, N. Y. Both of these

cases have been investigated. The conditions surrounding the latter indicate that the insect was present in small numbers and vigorous means were immediately taken by the New York department of agriculture and the superintendent of parks of Brooklyn, N. Y., to eradicate it. This work was supplemented by a small amount of scouting work carried on by this bureau. Further scouting should be done during the winter, and if no extension of the colony is found it should be possible to exterminate the insect in this locality within a reasonable time.

The New Jersey colony of the gipsy moth proved to be one of long standing, and the situation is complicated by the fact that large numbers of shipments of trees have been made from and near the colony to many destinations. A record of all shipments has been secured, which shows that stock has gone to 14 different States besides New Jersey. These shipments are being traced as rapidly as possible, and already two infestations in New Jersey, one in Pennsylvania, and one in New York have been located.

Preliminary scouting work by employees of this bureau has shown that the infestation at Somerville occurs in an area of about 100 square miles. The area will probably be increased later, when effective scouting can be done after the leaves are off the trees. The gipsy moth situation, both in New England and elsewhere, is extremely serious at the present time. Sufficient funds are not available to carry on the work effectively, and unless more very thorough work is done the insect is bound to spread rapidly.

The very high cost of supplies and equipment, together with the high price and scarcity of labor, further complicates the successful handling of this problem. Unless adequate funds can be secured to meet this emergency, there is little possibility of preventing the spread of this insect or keeping it within reasonable bounds.

SOUTHERN FIELD-CROP INSECT INVESTIGATIONS.

Investigations of southern field-crop insects have been continued under the direction of Dr. W. D. Hunter.

Cotton insects.—Owing to rapid development in the studies of boll-weevil poisoning, the work at the Delta laboratory at Tallulah, La., for the fiscal year has been largely limited to different phases of this particular problem. Practical control work conducted in cooperation with cotton planters was extended to include more than 50,000 acres of cotton during the growing season of 1919, and was further expanded in the spring of 1920. Results on the whole have been very satisfactory, and have served as a basis for numerous circulars of advice which have been issued for the benefit of farmers undertaking commercial poisoning work. This method of control has spread very rapidly. During 1918 poisoning was practically confined to the properties under the supervision of the experts from the Delta laboratory. In 1919 the farmers themselves took it up, and during the season approximately 3,000,000 pounds of calcium arsenate were used. The results were so good that in 1920 the demand for this chemical was greatly increased, and, while no accurate figures are available, the total amount of calcium arsenate sold for use this year surely exceeds 10,000,000 pounds.

Effort has been made to reach every man who is poisoning, and to aid him with such advice as seems best suited for his particular case. Consequently it has become necessary to extend the work to include new territory and new conditions. New field stations have been established in southern Louisiana, central Mississippi, southern Alabama, eastern Georgia, and southern South Carolina. In each of these localities observations are conducted to determine the activities of the weevil under the different conditions prevailing as affecting poisoning operations. Close check is also kept on the work of the farmers. The results secured are carefully noted and the conditions influencing these results are studied in an effort to standardize advice. Throughout all of this work, as well as the operations conducted under the direction of the Delta Laboratory, unpoisoned check plats are maintained under varying conditions in order that the exact limitations of profitable weevil control may be determined.

Semitechnical studies, consisting of plat work and cage studies, are being continued with a view of improving methods of poisoning.

The extensive production of calcium arsenate has necessitated the development of a very large project handled in cooperation with the Federal Insecticide and Fungicide Board. Improperly made calcium arsenate may either fail to control the weevil or may kill the cotton plant. Prior to 1919 the manufacture of calcium arsenate was limited, while at the present time over 20 companies are in the market, and this has meant the production of large quantities of inferior material. For their protection, farmers have been advised to buy this chemical on certain specifications and to send samples of the material purchased to the Delta laboratory for analysis before using it. This has resulted in preventing the use of large quantities which would have been very destructive to the cotton, and has involved the analysis of over 2,000 samples of calcium arsenate. These analyses have been made by chemists in the employ of the Insecticide and Fungicide Board. In addition the official inspectors of this board have been assigned to the work and have sampled many of the larger shipments. Portions of each of these samples are tested on plants at the Delta laboratory, and if found dangerous court proceedings have been started and seizures made under the insecticide act of 1910. This work has resulted in saving many crops of cotton and has prevented weevil poisoning from becoming too dangerous and thus falling into disrepute.

Another important phase of the investigations has been the development of suitable dusting machinery. Motor-power dusters proved unsuitable owing to the type of labor available for operation, and a new machine operated by wheel-traction power was developed in cooperation with the Bureau of Public Roads. Blue prints were prepared covering this type of machine and furnished to all interested manufacturers. Several models were placed on the market and more manufacturers are taking them up. The experimental department is now at work developing a cheaper form of wheel-traction machine which will be suitable for the small farmer who has an area too large to cover with hand guns. In additon to this work, manufacturers have been encouraged to forward test machines, many of which have been tried out and advice given for their improvement, all aiming toward providing the cotton farmer with the best and most

effective type of dusting machinery. This question has been so important that a special bulletin (Farmers' Bulletin 1098) has been issued for the use of both farmers and manufacturers.

Much work has been conducted on cotton varieties in relation to weevil injury, weevil hibernation, etc. In addition, the weevil dispersion line for the fall of 1919 was determined.

A Department Bulletin, No. 875, "Cotton Boll Weevil Control by the Use of Poison," prepared during the fiscal year 1920, has been issued since the close of the year.

A study of the field biology of the cotton boll weevil has been completed at the field station of the bureau at Madison, Fla., and the manuscript has been prepared for publication.

During the year a thorough study of the relationship of temperature to the immature stages of the boll weevil was undertaken, with special reference to the application of control measures. During the month of June, 1919, the high soil temperatures at Madison, Fla., caused a mortality of 98 per cent among weevils of the first generation. In other words, there were no more weevils in the field on the 5th of July than were present on the 5th of June, in spite of the fact that time had elapsed for the first generation. These studies indicated that for certain localities in the southeastern Gulf Coast States control experiments could have been inaugurated on the 5th of July with just as good chance of success as had such experiments been performed on the 5th of June.

The field biology of the boll weevil was found to present a considerable variation compared with the biology under insectary conditions. The average time from egg to adult under insectary conditions is approximately 14 days. The studies in the field show that the time from egg to adult, where the weevils are allowed to hatch on the soil beneath the plants, is approximately 22 days. This important discovery has a very direct bearing on the application of methods of control, especially where the time interval between applications of poison is concerned.

A good deal of attention has been given to the possibility of growing sea-island cotton under boll-weevil conditions. Sea-island cotton has been abandoned in almost every section where the weevil has made its appearance. The studies at Madison, Fla., indicate a possibility of making a very profitable crop on certain of the light sandy soils. The studies along this line are being continued and it is expected that some very valuable information will be gained.

Tobacco insects.—The tobacco hornworm continues to be the most important insect pest of tobacco in Kentucky and Tennessee. The shortage of labor and the consequent high wages affect the problem of control. Under former conditions growers did much hand worming during certain periods when labor could thus be advantageously employed, but under present conditions labor is so scarce that the control of the hornworm can be better accomplished by the use of dusting machinery, even when worms are not very abundant. This condition has brought the machinery problem to the front, and has resulted in the devising of a mule-drawn duster which applies the dust poisons to two rows at the same time and much more thoroughly and with much less labor than with the hand duster. This machine will be thoroughly tested and developed during the coming summer.

The labor shortage has also brought the problem of dosages into prominence. The question now to be solved is not to find the minimum dosage that will satisfactorily kill the worms present upon the plants, but to find a dosage that will be effective upon the worms for the longest possible period without injury to the plants. Experiments during the year show that under some conditions twice the usual amount of arsenate of lead was economical when compared with the usual practice of one lighter dosage plus even a moderate amount of hand worming. In one particular experiment the saving of labor amounted to $5 per acre, and the conditions in this particular field occurred quite generally over the entire so-called Black Patch in Kentucky and Tennessee.

Careful tests of calcium arsenate in comparison with arsenate of lead were made, and the results indicate that the use of calcium arsenate is not to be recommended for tobacco. Even grades containing a very low percentage of water-soluble arsenic oxide injured plants more seriously than did the arsenate of lead.

An important new line of investigation has been started, the result of which can not be determined until the summer of 1922. This work included nearly 1,000 acres of tobacco in Kentucky and Tennessee upon which an effort will be made greatly to reduce the hibernating generation of hornworms by killing them with insecticides upon the suckers, which often grow to great luxuriance after the tobacco crop is housed. The region selected is one in which the growers are the most wide-awake and in which they control the hornworm very well, indeed, during the growing season. If there is anything to be gained by a fall control of the hornworm, the region selected offers the best opportunity for the determination of the value of such control. This suggestion was made by the chief of the bureau for tobacco insects in general more than 20 years ago, but has never been tested on a large scale.

The mosiac-disease work was stopped almost completely during the winter because of the resignation of the investigator who had it in charge. This work has been reassigned to S. E. Crumb, who already has determined one means by which the disease overwinters and has started a comprehensive series of experiments upon the epidemiology of the disease.

The work on tobacco insects at Quincy, Fla., has been divided principally between two primary insect pests—the tobacco thrips and the tobacco flea-beetle. It has been shown that undoubtedly the best time for attacking both of these pests is during their emergence from hibernation, when the plants are small, and sprays and dust mixtures can be more easily and more thoroughly applied.

Through cooperation of one of the manufacturers of spraying machinery, a special power sprayer was secured which is sufficiently narrow to go between two rows of tobacco. However, owing to certain faults in construction and owing to the late date at which this machine was received, it was impossible to use it between the rows this year, but before tobacco was tied up to the top of the sheds the mule machine was mounted upon a farm wagon and five rows of tobacco were sprayed at a time. The results indicate that this method of control is sound, and that undoubtedly this type of machine, when the faults in construction are remedied, will be very valuable to the growers.

The tobacco flea-beetle during 1919 damaged tobacco in some fields at Quincy to the extent of $600 per acre. A power duster has been secured for the bureau's experiments, and it has been found that a mixture of equal parts of calcium arsenate and tobacco dust, or lead arsenate and tobacco dust, when applied at the rate of 8 to 20 pounds to the acre (usual dosage ranging from 8 to 12 pounds), resulted in a very satisfactory control. However, it was found that late in the season considerable burn resulted from the use of calcium, and the problem during this stage of growth resolves itself into a test of the feasibility of using lead arsenate instead of calcium arsenate in the tobacco dust poison mixture. The objection to the use of lead arsenate is due to its quality of adhering to the leaves, and thus presenting unsightly spots upon the cured wrappers. It is hoped that lead arsenate used in the tobacco dust mixture will wash from the plants sufficiently to overcome this objection.

The use of calcium arsenate in the budworm-control mixture results in severe burning except under the most favorable conditions, and this insecticide must be abandoned for budworm control.

Hornworm control on shade tobacco in Florida is also a serious problem late in the season. Arsenate of lead can not be used straight, because of the "painting" of the leaves and the consequent unsightly appearance of the cured wrapper. Paris green and calcium arsenate are dangerous and injurious except under the most favorable weather conditions. Experiments are under way to ascertain whether a mixture of arsenate of lead and tobacco dust can be used more satisfactorily.

Sugar-cane insects.—The work for the fiscal year 1920 in Louisiana has been devoted mainly to the introduction of Cuban parasites of the sugar-cane moth borer. In the summer of 1919 E. R. Barber was stationed in Cuba, and sent in about 900 puparia of a tachinid parasite (*Euzenilliopsis diatraeae*), which were successfully established on four Louisiana plantations. It remains to be proved whether the parasites lived through the winter.

The work was continued this summer, but on a much larger scale, funds having been subscribed by a number of progressive sugar planters in support of the work. Mr. Barber went to Cuba in April, accompanied by four student assistants. Several thousand puparia have already been sent in. These are being cared for in a specially designed insectary in which everything is arranged to provide for a maximum of light and air, and owing to special facilities a minimum of time is required in handling the parasites.

Having emerged from the puparia, the flies are allowed to feed and later are taken to the fields in small cages. Positive proof is expected this year as to whether the introduction of Cuban parasites is feasible and whether they can survive the Louisiana winter. If the winter is too cold for them, it may be possible to keep them over in greenhouses, and some sugar planters have suggested reintroducing them every year.

The work of the station at Brownsville, Tex., has been devoted mainly to an intensive study of the biology and control of the sugar-cane borer and its control in the Rio Grande Valley of Texas. Considerable attention has also been paid to the occurrence of the

species upon Johnson grass, Sudan grass, kafir corn, and other plants.

In conjunction with the parasite introduction campaign being conducted in Louisiana, large numbers of larval parasites of the cane borer have been released in the most heavily infested sugar-cane and corn fields. Unfortunately, climatic conditions were such during the winter of 1919–20 that an unusually small number of cane borers survived and the infestation so far this year has been remarkably light. For this reason it is yet too early to determine whether the parasite has been able to establish itself. Under normal conditions the introduction of these parasites promises to be the most simple and effective control measure that can be adopted. A very efficient egg parasite is already present over the greater portion of the infested territory, which at certain seasons destroys about 75 per cent of the total borer eggs deposited.

Experiments during the hibernation period have also proved that under Rio Grande Valley conditions old cornstalks lying in the fields through the winter may be as dangerous, if not more dangerous, than sugar cane under the same conditions, owing to the larger number of wintering larvæ present in cornstalks. For this reason strong recommendations have been made regarding the destruction of cornstalks during the winter. With the high price of cane prevailing, the cane fields generally have been cleaned up very thoroughly, and in two locations at least even the old tops have been used for planting in order to release more cane. This no doubt has been an important factor in the scarcity of borers in the cane fields so far this year.

During the year the cane borer has been discovered in a number of widely separated localities in Texas where it has not previously been known to occur. This includes a number of points along the Gulf coast. For this reason it is important that the general distribution be determined, and a survey has been planned for the near future to cover the infested territory and to discover how far the pest has spread.

INSECTS AFFECTING THE HEALTH OF MAN AND DOMESTIC ANIMALS.

Insects affecting domestic animals.—Under the project "Control of the House Fly and Other Insects in Establishments Operating under the Federal Meat Inspection," cooperation was continued with the Bureau of Animal Industry. Progress was made in further perfecting flytraps and baits. Some experimental evidence was obtained as to repellent and attractive chemicals and the possibilities of their use in controlling the house fly and various blow flies. The Bureau of Animal Industry inspectors in charge of the various stations have been proceeding with the work as advised by the Bureau of Entomology, looking toward the permanent abolition of favorable fly-breeding grounds around packing houses and abattoirs.

Screw worms.—It has been conservatively estimated that the average annual loss due to this pest is $4,000,000. There also is a considerable loss due to the wool maggots of sheep. Investigations have been carried out along several lines. A field station has been established in the heart of the sheep and goat raising regions of Texas

near Sonora. It is the purpose to put into actual practice on the range these control principles which have been more or less fully worked out, and observe the results. These practices consist mainly of (1) carcass burning, (2) trapping of flies, (3) poisoning of flies, (4) avoidance of screw-worm attack through various modified range practices, and (5) the development of a satisfactory larvicide and repellent for use on wounds.

During the latter part of the year an active cooperative arrangement was entered into with the Texas experiment station. In the future the field work will be carried on at the Texas substation No. 14, near Sonora, Tex.

The difficulty of securing an effective and convenient bait for use on the ranges has been largely solved by the production of dried gut slime. The fresh slime, a by-product of the meat-packing houses, has been used with much success as a blow-fly bait for several years. The discovery that this product can be greatly concentrated and made available for shipment through drying and at the same time retain most of its attractive principles is an important step forward.

Considerable progress has been made in the development of more efficient repellent mixtures for wounds.

Horseflies.—The investigation of the horsefly problem in the Southwest, in cooperation with the Nevada experiment station, was discontinued with the close of the last season. The life history and habits of the principal species were rather fully studied. Many control measures suggested were found to be impracticable under ranch conditions. It was rather conclusively shown that the drainage of the swampy areas and the substitution of more intensive cultivation of the farmed areas, substituting alfalfa, grain, etc., for the native grass meadows, will be necessary to reduce materially the losses from these flies.

Ox warbles.—Work on the two destructive species of ox warbles has been continued in various parts of the United States. Further experiments have been carried out which will prove that the larvæ hatch and penetrate through the skin on the heels or elsewhere where the eggs are laid. Moreover, these larvæ, at least in part, go to the gullet of the host before passing to the subcutaneous tissues of the back. A large amount of information on other points in the life history, seasonal history, distribution, and injuriousness of the pests has been obtained. Experiments have also shown that the larvæ can be effectually and economically destroyed by placing certain compounds in the holes in the hide on the backs of cattle.

Poultry parasites.—A species of mite (*Liponyssus sylviarum*), not heretofore known as a poultry pest, has been found to occur in injurious numbers in several flocks of chickens in different parts of the United States. An effective control method has been developed, and eradication proved possible through its actual accomplishment in one heavily infested flock.

The depluming mite of fowls has been studied and a simple and effective remedy found.

Insects and hog cholera.—During the summer of 1919 an agent was assigned to cooperate with the Bureau of Animal Industry in studying the possible transmission of hog cholera by insects. Earlier work of the Bureau of Animal Industry showed that both the house

fly and the stable fly were capable of carrying the disease for short periods under certain conditions, this suggesting the desirability of securing more data on this subject, and especially to determine if some insect might be responsible for the appearance of cholera at various points sometimes far removed from known cases of the disease. Experiments were carried out with the house fly, stable fly, and Simulium. The first two species gave positive transmissions in a number of instances, the results on the whole agreeing closely with those previously obtained by the Bureau of Animal Industry. Studies were also made of the insect fauna of hog excrement and the various ways in which insects are associated with hogs. These should aid in epidemiological studies of the disease.

Insects affecting the health of man.—The work of the bureau laboratory at Mound, La., was materially narrowed during the war period by service in the Army on the part of the force at that station. This condition continued throughout the greater part of the fiscal year 1920. Two definite lines of work were continued having for their objective further definite information on the biology of malaria mosquitoes and the practical antimosquito measures that apply in the prevention of malaria on plantations and farms. These lines consisted of the determination of the relative density or numbers of Anopheles in and about plantation houses under varying environmental conditions and the relative capacity of various classes of surface water in Anopheles production, together with the effect of such production upon the adult density. During the year the United States Bureau of Fisheries completed cooperative studies on the mosquito-eating fish of the region under observation.

Former lines of work upon the effect of malaria on crop production and agricultural development, upon the relative efficiency of the various species of American Anopheles mosquitoes to act as the hosts of the malaria parasites, upon the breeding requirements of Anopheles larvæ, upon the density and food requirements of adults for malaria transmission, and upon regional distribution of Anopheles in respect to topography, agricultural operations, and agricultural development have not been resumed through shortage of funds.

Malaria, the prevention of which is entirely a biological problem based upon the control of Anopheles mosquitoes, costs the United States, and particularly the South, millions of dollars annually in loss on crop returns and in checking agricultural development. The land areas included in the malaria regions are the most fertile lands in the United States. The medical side of the problem is well understood and cared for by the proper treatment. The Government is spending enormous sums of money for protection in small towns and in certain cities through the Public Health Service. The agricultural side is neglected and little understood. The rural side of the problem overshadows all other interests in importance. It is the side upon which definite constructive information is lacking. The investigation is worthy of ample support, the work is within the function of the Bureau of Entomology, and it is advised that in order to hold the present work together and continue the same efficiently further provision must be made for men and for facilities.

House-fly control.—A test was begun about two years ago of the durability of various types and grades of screen-wire cloth as used

for protection against flies and mosquitoes. This experiment was undertaken through cooperative arrangement with several State experiment stations, agents of the Bureau of Entomology, and other agencies in about 14 sections of the country, the object being to gain information as to the most economical and effective screen under various climatic conditions. While this test must be continued for several years longer to determine the durability of many of the kinds of wire, some information of value is already obtained. It appears that there is much variation in the durability of certain screenings of the same class and cost, probably due to methods of manufacture. It also appears that in some regions black wire (painted) is even more durable than some kinds of the higher-priced galvanized screens.

Investigations of insects breeding in human excreta.—Wilmington, N. C., field station: Owing to lack of funds it was found necessary to discontinue this project. The agent in charge of these investigations was transferred from the bureau on May 31. During the time he was assigned to the project he did very efficient work in rearing the various species of flies which breed in human excreta. Shortly before he resigned from the bureau he had begun experiments with chemicals for the prevention of fly breeding. There was not enough time to reach definite conclusions as to the effect of the chemicals. However, the greatest promise was shown by potassium cyanide solution, sodium arsenate solution, and a pine-tar product acid.

TROPICAL AND SUBTROPICAL FRUIT INSECT INVESTIGATIONS.

The work in tropical and subtropical fruit insect investigations is under the charge of the Assistant Chief of the Bureau, C. L. Marlatt.

Investigations of insects affecting citrus fruits in California.—The research work of this station has been largely a continuation of the investigations of liquid hydrocyanic acid for the fumigation of citrus trees. The use of this liquefied gas is largely replacing and probably will ultimately almost entirely replace the old methods of citrus fumigation with gas developed under the tree at the time of fumigation by a combination of the proper chemicals. The special work of this year has been a study of the diffusion of liquefied hydrocyanic acid under various temperatures and the effect of the gas on citrus insects as the temperature is reduced. Attention has been given the subject of daylight fumigation, and it is evident from the results thus far obtained that fumigation of dormant citrus trees during the day is possible providing the proper dosage and exposure are employed.

The Argentine ant investigations referred to in the report for the fiscal year ended June 30, 1919, have been continued, owing to the fact that some of the ant poisons recommended crystallized during cold weather and soured in the presence of a humid atmosphere, and as a result it has been necessary to modify some of the formulæ to meet winter conditions. Considerable time has also been devoted to instituting ant-control campaigns in citrus centers where the Argentine ant is abundant. A number of papers dealing

with insect problems in California have been published during the year.

Citrus fruit insects in Florida.—The work under this project has been a continuation of that described in the previous report. The value of the dust method for controlling rust mites has been determined and many demonstrations have been conducted throughout the State. Cooperative work with the Bureau of Plant Industry has been carried on for the purpose of developing a combination spray which will be effective against insects as well as plant diseases. As in the past, considerable attention has been given to the control of the citrus white fly and the scale insects which commonly infest citrus plants in Florida.

Investigations of insects affecting mango, guava, avocado, and other subtropical fruits.—During the year the insects infesting the plants listed above have been studied at the Miami station. A paper has been published on the banana root-borer, and several papers are in course of preparation describing the life history and methods of controlling the principal injurious insects infesting the avocado, mango, and papaya. The work of this laboratory has been in close cooperation with the Federal Horticultural Board in an effort to safeguard against the introduction of insects injurious to tropical and subtropical plants.

Studies of greenhouse insects.—The work under this project has been for the most part limited to the study of the strawberry root-worm, an insect which in recent years has developed into a serious pest to roses grown under glass. This insect is now established in widely separated localities and is reported to have been responsible for the loss of some $70,000 in one county alone in the State of Pennsylvania during the present year. In order to study this insect under field conditions a temporary station has been located in Pennsylvania, and active work is being conducted in collaboration with the Pennsylvania State Department of Agriculture.

An investigation of the chrysanthemum midge has been completed, and a bulletin (Department Bulletin 833) has been published, giving general information on the life history, habits, and methods of controlling this chrysanthemum pest.

Mediterranean fruit fly and melon fly.—As heretofore, the work at the laboratory at Honolulu has consisted primarily in the inspection and certification of pineapples, bananas, coconuts, and taro for shipment from Hawaii to the mainland. Further studies have been made to determine the effectiveness of parasites and other natural enemies in controlling the Mediterranean and melon fruit flies. In addition to the fruit-fly problems, a study of the principal insect enemies of the algaroba bean—an important stock food—has been undertaken in collaboration with the Office of Stored Product Insect Investigations.

Geographical distribution of fruit flies.—A survey was made in Spanish Honduras to determine the injurious fruit flies and tropical and subtropical fruit insects which are present in that country and which may enter the United States in shipments of fruit to southern ports. A number of injurious tropical and subtropical insects were found and a report of this trip is in the course of preparation.

Investigation of fruit flies and other tropical and subtropical fruit insects in the Canal Zone, Panama.—The work of this project has been somewhat curtailed during the year owing to the loss of the services of the assistant in field charge. The work has, however, been conducted in a modest way and additional facts have been secured concerning the life history, habits, and distribution of the so-called black fly of citrus, which has been established in the Canal Zone for several years. The survey of injurious insects established in the Canal Zone has been conducted primarily for the purpose of determining the injurious insects which may be brought to southern ports in cargoes of fruit.

Investigation of camphor thrips.—A study of the camphor thrips was undertaken for the first time this year and a temporary field station was established at Satsuma, Fla. The work in this laboratory included the life history and methods of controlling this thrips in nursery stock and camphor plantations. Although this work has been under way for a comparatively brief period, substantial progress has been made.

BEE-CULTURE INVESTIGATIONS.

The work of the Office of Bee Culture Investigations, under Dr. E. F. Phillips, as formerly, has been largely a continuation of the work instituted during the war for the increase in honey production, while at the same time an effort is being made to take up again some of the investigational work which was dropped during the rush of war activities. The educational work begun during the war has proved so beneficial and so popular that it is not desirable or even possible to discontinue it. The laboratory and apiary are still located at Somerset, Md., near Washington.

Demonstrations in bee culture.—The funds available for this work were reduced this year by the loss of the funds available under the food-production act, and because of this decrease it was necessary to drop the work in some States. In deciding which States should no longer receive aid from this office an effort was made to discontinue this aid in those States where the project would be continued on much the same scale by the States alone, and in most cases this was done. At present in every case where this office contributed to the work it is supported by both the States and this department, and, as it is now expected that the demonstration work will be a permanent feature, plans have been made for the entire administration of the movements of the extension men by the several cooperating extension divisions. In all, seven States are now cooperating with the office in this work. While during the war it was possible to obtain the services of men willing to make a considerable financial sacrifice, it is now virtually impossible to get competent men who will take up this work for the salaries offered because of the greater income possible from honey production by those fitted for the extension activities in beekeeping. It is therefore not feasible to increase the extension work in beekeeping rapidly with the present salary scale.

The work of the demonstration men has been along the lines mentioned in previous reports, the only change being that gradually

they are devoting more of their time to those who aim to make beekeeping their life work and who, therefore, are willing and able to carry out the plans of honey production advocated by the department. The specialization in beekeeping, which has been noticeably increasing during the last few years, has received a great impetus from the growth of beekeeping during the war, and it is now clear that the future of beekeeping rests in making better beekeepers of those extensively engaged in the work rather than to induce more people to take up the work.

Mention was made in the last report of a new type of extension work that was being tried, namely, the holding of schools for commercial beekeepers, each of a week's duration. It is obviously impossible in short meetings to present the subject of beekeeping in a comprehensive manner, and in order that the teachings of the office might be presented better these schools have been continued and have been received with enthusiasm wherever presented. Since these are conducted by men from the office and not by the regular extension men, the number which can be presented is limited. During the year 11 such courses were given and 2 others were discontinued at the last minute because of the influenza epidemic. The average attendance at these schools was well over 100, which is about as large a number as can be handled efficiently. While these schools are planned for commercial honey producers, it is found that those not yet heavily engaged in beekeeping but who desire to take up the work are able to attend these schools with profit, and at each school there have been several such persons in attendance.

The bulletin on swarm control, mentioned in the last report, has been completed but not yet published. Two manuscripts of a practical nature have also been prepared during the year, one on beekeeping methods applicable in the buckwheat region and the other in the region where tulip tree is the major source of honey. It is believed that many beekeepers fail to take full advantage of the department's publications in which the principles of beekeeping are presented, because of the difficulty of making the necessary local application, and it has therefore semed wise to prepare detailed and specific directions which will apply to certain designated regions, and to no others, in order that they may be more readily followed. It is hoped to prepare other bulletins of this character as soon as data are available, one other having already been partially prepared.

Wintering of bees.—The object of the work on wintering is, of course, to provide methods whereby the beekeeper may not only save his bees from death during the winter, but whereby the colonies may be able to build up rapidly in the spring to reach maximum strength in time for the honey flow. In order to have a better understanding of the latter phase of the problem, measurements were begun with the first brood of the season of 1920, and at weekly intervals the exact amount of brood in each of several colonies was determined. This gives not only the total amount of brood reared by each colony before the honey flow, but also shows changes which occur in the rate of development. This work was continued up to and then through the honey flow. The making of the observations in an exact manner takes so much time that it has not yet been possible to analyze the data, but from what are now at hand it is clear that this work offers

information which will prove valuable to the beekeeper. This phase of the problem is being undertaken by Lloyd R. Watson, and he will as rapidly as possible get the data into shape for presentation. In all probability it will be necessary to repeat the work on other colonies another year before presenting it in bulletin form.

The loss of bees during the winter of 1919–20 was excessive, owing partly to the fact that beekeepers did not give the attention to this work which it demands, but largely to the fact that in some regions there was a shortage of nectar in the fall; and, as sugar was not available for the feeding of bees, many beekeepers were compelled to put their bees into winter quarters with insufficient stores or with honey of poor quality. The losses of the winter, which was a most severe one for bees, will scarcely be made up by the increase made by beekeepers during the present summer. Because of this great loss, every effort is being made to spread the information regarding the methods to be used to prevent a recurrence of the loss another winter, but it is realized that it will take many years to get even the commercial beekeepers of the country fully to realize what can be done by the use of better methods. The wintering problem in beekeeping has now become largely a problem in education.

Diseases of bees.—This project has been continued without interruption. During the year a Farmers' Bulletin (No. 1084) was issued giving the best-known methods for the treatment and control of American foulbrood. Two papers, one on American foulbrood (Department Bulletin 809) and one on European foulbrood (Department Bulletin 810), were issued during the year giving the results of investigations on these diseases, which were completed several years ago but which were delayed in presentation. A most important contribution of the year on the subject of bee diseases was a paper detailing the activities of bees in cleaning out European foulbrood (Department Bulletin 804), it now being clear that the control of this disease lies in getting the bees into such condition that they are able of themselves to clear out every trace of the infection. During the year 700 samples of brood were examined for beekeepers and apiary inspectors.

Considerable work has been done on the factors influencing the distribution of European foulbrood. It has been found that this disease can not continue in regions where there is an early heavy honey flow, and from the records of the office for the last 14 years it is possible to indicate quite clearly those regions where there is reason to take preventive measures against the disease. Combined with this work must go a study of the beekeeping resources of the various parts of each State. This work is being continued, and it is hoped that in the near future a bulletin may be prepared showing the present distribution of the disease according to the records, and also pointing out in each region the factors which reduce or increase the danger from this serious disease. This work will show where it is most necessary to apply the methods already discussed in previous publications of the department.

Beekeeping after the war.—In previous reports mention has been made of the effects of the war on beekeeping, and it may be well to point out the trend of the industry since the armistice. The stimulus to beekeeping which resulted from the war has become even more

marked since the cessation of hostilities, and beekeeping is still increasing in extent and importance at a rapid rate. The dealers in beekeeping supplies, the breeders of queen bees, and those who deal in full colonies of bees have during the present season faced the largest demand for their goods in the history of the business as a commercial enterprise. The subscriptions to the journals devoted to beekeeping are rapidly increasing and the demand for beekeeping literature, both that from the department and that published privately, is the largest in history. A factor which contributed largely to this continued increase in the importance of beekeeping was the fact that sugar was scarce, but this does not by any means fully explain the great present demand for honey or the fact that so many beekeepers are engaging still further in the industry. Honey is now being used in the manufacture of ice cream and in confectionery, but the greatest demand is, of course, for home consumption, and this demand is greater at present than ever before. The demand for honey for export, which was so important a factor during the war, has virtually ceased, because of the rates of foreign exchange, but in spite of the fact that American beekeepers looked for a continuation of this demand as an important factor in the future of the industry, the loss has been fully made up by the increased demand for honey at home.

There has been a tendency for the last 20 years toward the development of beekeeping as a specialty, and this has been considered as a desirable condition, rather than that bees should be kept on every farm. The heavy winter losses of 1917–18 and again in 1919–20 resulted in the loss of most of the colonies in the hands of careless beekeepers. Furthermore the beekeepers who kept only a few colonies failed to realize the demand for more honey, while those engaged in the work as a major occupation were able and anxious to take full advantage of the opportunities presented. This combination of circumstances has greatly hastened the placing of beekeeping on the basis of a specialty in agriculture, and to-day the industry is further ahead by 20 years than it would have been without the stimulus of the war and the severe losses of winter.

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